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# Currency in Circulation, the Cash Changeover and the Euro-Dollar Exchange Rate*

By *Franz Seitz* and *Ulrich Bindseil*

## Contents



## I. Introduction

The main purpose of this paper is to analyse the evolution of currency in circulation in the euro area since 1999. In this regard we also revisit the thesis put forward by some authors the most prominent of them being the president of the Ifo Institute of Economic Research (see e.g. Sinn and Westermann 2001) that the fall in the euro/dollar exchange rate since the start of 1999 is explained by the decline of the demand for euro banknotes in the wake of the change-over from the old euro cash (the national denominations of the euro) to the actual euro cash.

The following details of the cash change-over may be briefly recalled: from 1 January 2002, euro banknotes and coins have legal tender status. The former national denominations of the euro lost this status on 1 March 2002. Euro banknotes and coins were "frontloaded" to banks and retailers as from 1 September 2001, in order to ensure adequate cash supplies as from 1 January 2002. Most ATMs dispensed euro as from 1 January 2002 and retailers in principle gave change in euro as from that day. Exchange of national currencies for euro took place, free of charge until including March 2002, at credit institutions, national central banks or dedicated exchange points. National central banks will exchange their respective national banknotes against euro free of charge at

* We thank *G. Camba-Mendez* and *A. Hirsch* for providing us with their trend of banknotes, *A. Rees* for providing us with his exchange rate model as well as *D. Blenck*, *F. Papadia*, *R. Porter*, *G. Weinbach* and two anonymous referees for useful comments and information. The paper reflects the personal views of the authors and not necessarily those of the European Central Bank.

least until the end of 2012. The bulk of transactions was in euro from the start of January onwards. In August 2001, the Eurosystem launched an information campaign on the euro coins and banknotes and the cash change-over to raise awareness of the people of Europe. The ECB also took several measures to facilitate a smooth cash change-over for the holders of national denominations of the euro outside the euro area, namely to frontload euro banknotes to central banks outside the euro area and to allow them to sub-frontload credit institutions having their head or registered office in their jurisdiction from 1 December 2001. Also, national central banks of the euro area were allowed to frontload non-euro area credit institutions specialising in the wholesale distribution of banknotes, upon request and subject to certain terms and conditions.

An early impact of the approaching cash change-over on the circulation of euro area currency has emerged more and more clearly since the beginning of 2001 (see e.g. ECB 2001a, p. 10; and the survey results presented in Stix 2001). Sinn and Westermann (2001) take the decline in currency in circulation as a starting point to argue within an explicit two country portfolio model with money, bonds and shares, that the "prosperous-economy explanation" of the strong dollar is wrong. In their view there is little reason to expect a country's profit expectations to translate into the exchange rate, because these are already reflected in share prices. Instead, they argue that the demand for money in the narrow sense of the word counts most. According to Sinn and Westermann (2001) it is mainly the use of DM currency by the shadow economy and in countries of Eastern Europe and the exchange of those against US dollars which is responsible for the declining euro. The exchange rate is the price of one type of money in terms of another, they argue, and not the price of interest bearing assets, as both portfolio managers and economists who developed the portfolio balance approach have claimed.[1] This theoretical result is claimed to be confirmed by a number of empirical tests of the exchange rate which demonstrated a strong and robust positive correlation between Germany's stock of currency in circulation relative to the one in the US and the exchange value of its currency, or the euro, for that matter. The authors conclude from this by suggesting doubts about the way the euro was introduced. Instead of first introducing the euro as a virtual currency, allowing for an extended transition period between the announcement and the physical launch of the new currency, a big bang would have been preferable, according to Sinn and Westermann.

In the present paper, we revisit the conclusions of Sinn and Westermann (2001) by arguing that an effect of the amount of banknotes in circulation on the exchange rate is neither theoretically necessary nor appears to be empirically evident. The paper proceeds as follows: section II presents some stylised facts on the development of currency in circulation in the euro area and in the US since the middle of the nineties. Section III describes how a substitution of euro banknotes by dollar banknotes affects the balance sheets of central banks and how central banks neutralise the effects on the domestic money market. Section IV provides an empirical analysis of the relationship between the US dollar and

[1] Both the portfolio balance model and the monetary approach emphasise the role of money for the determination of the exchange rate, see e.g. *Obstfeld* and *Rogoff* (1996, ch. 8.2.7.); *Chinn* and *Alquist* (2000); *Goldberg* and *Frydman* (2001) and *Husted* and *Melvin* (2001, ch. 7 and 8). But neither postulates that "money" has to be "cash".

euro banknotes time series and the exchange rate between the two currencies. Finally, section V summarises and concludes.

## II. The Evolution of Euro Area and US Dollar Currency in Circulation

Chart 1 shows the evolution of Euro and US dollar currency since 1994 on a weekly average basis.[2] Table 1 provides further key figures. Both currency series exhibit a clear cut seasonal pattern due to intra-yearly (see e.g. the situation at the end of the year), intra-monthly (e.g. the payment of salaries) and fixed and moving holidays' effects. The seasonality between the two areas appears to diverge in so far as both the Christmas and the Summer season seem to be stronger in the euro area than in the US.[3] A plausible explanation is that the use of cash for the related specific activities, namely Christmas shopping and holiday travelling, is still more common in Europe than in the US, where credit card payments are more frequent. Also apparent in the figure is the well known Y2K effect: reacting to rumours that ATMs could not function after the millennium change, some people hoarded cash on both sides of the Atlantic, whereby the effect was somewhat stronger in the US. In both areas, the trend of currency in circulation rises until the end of 2000, although a temporary slowing-down of the growth rate could be observed in the euro area in 1998. Growth rates generally tended to be higher in the US than in Europe. But the relation of currency to nominal GDP in 2000 is equal. Overall, it appears that the similarities between the two time series are striking.

While growth continued in the US case in 2001, the euro area witnessed a decline of currency in circulation starting at the end of the year 2000 and gaining momentum in the course of the year 2001. The decline has been attributed univocally to the anticipation of the cash change-over, especially by holders of "black money" who fear that they may have problems getting rid of their old banknotes after 2001, hoarded cash and by holders of euro area currencies outside Euroland who also may be worried about the working of the cash changeover.[4] Regarding the last point it has been estimated that between 30% and 40% of German currency is held outside Germany (Seitz 1995). And recent estimates of shadow economy activities which are postulated to be undertaken mainly with cash suggest that for EMU countries the size varied between 10% and 28% of GDP at the end of the 90s (see Schneider 2001).

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[2] In the case of the euro area the currency figures always refer to banknotes in circulation.

[3] We choose the reference period 1994 to 1997 as the following years may be distorted by the beginning of stage 3 of EMU, the Y2K problem and the introduction of euro notes and coins.

[4] This development is also not surprising in the light of the efforts the EMU banking system and central banks have undertaken to get back as early as possible currency not used for transactions. The Bundesbank's and German banks' "Schlafmünzen" campaign alone attracted coins hoarded in piggybanks etc. siphoning off about DM 4 bn. in the first half of 2001 (Deutsche Bundesbank 2001, p. 3).

*Chart 1*

**Euro and US Dollar Currency (Bn €, Bn $)**

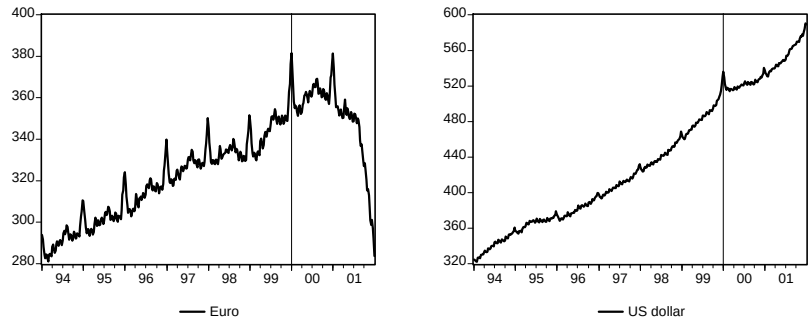



*Table 1*

**Annual Growth Rates of Currency and Some Information Items***

| | 95 | 96 | 97 | 98 | 99 | 00 | 01 | Currency / nom GDP[a] | Currency / capita[a] | Christmas effect[b] | Summer effect[c] | Y2K effect[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Euro area | 3.6 | 4.2 | 4.1 | 1.9 | 3.5 | 4.6 | -4.1 | 5.7 | 1,262 € | 1.07 | 1.01 | 1.10 |
| US | 7.5 | 4.4 | 6.6 | 7.1 | 10.5 | 7.1 | 5.0 | 5.7 | 1,949 $ | 1.05 | 0.998 | 1.17 |

* annual averages;

a) referring to year 2000.

b) average level of banknotes in the last 7 calendar days of the year compared to the yearly average over the period 1994 to 1997.

c) average level of banknotes in August relative to average banknotes in September over the period 1994 to 1997.

d) level of banknotes in the last 7 days of 1999 compared to the average 1999 level.

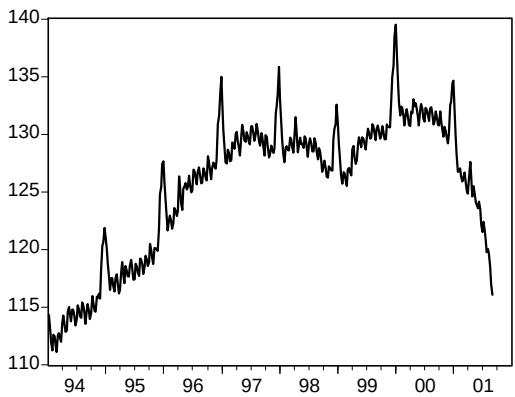
Finally, for illustrative purposes, it is also interesting to have a look at the national time series of currency in circulation in the euro area. Table 2 provides some key statistics. Interestingly, some heterogeneity appears, which seems to go beyond that between the euro area as a whole and the US. For instance, the banknotes in circulation as percentage of GDP vary between 2.3% (Finland) and 9.4% (Spain). Similar differences are obtained when looking at the banknotes per capita: the average euro area inhabitant held € 1,262 at end of 2000, with extremes being Germany (€ 1,631) and Finland (€ 573). Of course, these figures may be distorted by banknotes circulating outside the respective country.

The total growth of banknotes in the period from end 1994 to end 2000 has also been rather different across the euro area: having being on average 22.9%, it varied between 0.3% (the Netherlands) and 123.9% (Ireland). The different growth rates, as well as the differences in the relative levels as at end 2000, may be explained by the following factors: (1) different rates of economic growth (this is likely to explain a large part of the impressive growth in the Irish time series); (2) different (evolution of the) payment habits (e.g. banknotes against cashless payments); (3) a different relevance and evolution of the use of banknotes abroad; (4) possibly a different relevance and evolution of the black economy.

The decline in currency in circulation in EMU since the end of 2000 is widespread across euro area countries (ECB 2001a, p. 10 f.).[5] This seems to rule out the dominance of country-specific factors. For Germany, whose currency in total EMU currency in circulation was about 34% at the end of August 2001, it is worth also displaying a chart of the national time series (see chart 2). The developments broadly resemble those of the whole area with two exceptions: there is a temporary downward trend from mid 1997 until the end of 1998 and in 2001 the downward movement is much more pronounced than in the EMU as a whole. For instance, in mid 2001 the annual percentage decrease of currency in the euro area as a whole amounted to about -5% and thus was only half that of Deutschmarks. The decline in DM banknotes is most pronounced for the larger denominations of DM 1,000, DM 500 and DM 200. The first temporary downward trend has been attributed to uncertainties surrounding the beginning of stage 3 of EMU. The recent stronger downward trend should be related to the fact that DM banknotes are circulating to a higher percentage abroad, compared to other euro area currencies, and were hence potentially over-proportionally affected by the anticipations of the cash change-over.

*Chart 2*

**DM Currency in Circulation (Bn €)**




[5] In mid 2001, all but four countries in the euro area (Greece, Italy, Portugal, Finland) recorded absolute annual declines in currency in circulation.

*Table 2*

**Selective Indicators of Banknotes in Circulation in Euro Area Countries in 2000***

| | BE+LU | DE | ES | GR | FR | IE | IT | NL | AT | PT | FI | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total at end 2000 (in bn €) | 13.6 | 133.9 | 57.2 | 9.2 | 46.1 | 5.0 | 75.1 | 17.4 | 13.9 | 6.2 | 3.0 | 380.61 |
| Share in euro area total (in %) | 3.6 | 35.2 | 15.0 | 2.4 | 12.1 | 1.3 | 19.7 | 4.6 | 3.7 | 1.6 | 0.8 | 100.00 |
| In % of GDP | 5.1 | 6.6 | 9.4 | 7.6 | 3.3 | 4.8 | 6.4 | 4.3 | 6.8 | 5.4 | 2.3 | 5.8 |
| Euro per capita | 1280 | 1631 | 1444 | 871 | 782 | 1349 | 1310 | 1111 | 1720 | 625 | 573 | 1262 |
| Change since the end of 1994 (in %) | 32.8 | 10.9 | 29.9 | 69.2 | 13.3 | 123.9 | 45.3 | 0.3 | 26.6 | 47.4 | 39.9 | 22.9 |

* In billion euro.

Source of banknote figures: Publication of balance sheets of national central banks.

## III. A Substitution of Euro Banknotes by Dollar Banknotes and Central Bank Liquidity Management

To approach the problem of a possible influence of the amounts of banknotes in circulation on exchange rates from a monetary policy perspective, one may first have a look on how a change in the level of banknotes in circulation, or possibly a substitution by holders abroad of one type of currency by another, actually takes place and how the central bank balance sheet reacts to such a reduction or substitution. Consider the following simplified balance sheet of the Eurosystem:

**Stylised Eurosystem Balance Sheet***

| Assets | | Liabilities | |
|---|---|---|---|
| Monetary policy operations | 180 | | |
| | | Banknotes in circulation | 350 |
| Other autonomous factors | 340 | Liabilities to general government | 50 |
| | | Current accounts (incl. min. reserves) | 120 |

*Figures in billion of euro, approximate levels in 2000. The Eurosystem consists of the 12 participating NCBs and the ECB.

In the simplest possible representation, the balance sheet basically falls into three types of positions, namely monetary policy operations, controlled by the central bank's liquidity management, autonomous factors, which are not under the control of the central bank liquidity management, such as banknotes or government deposits, and the current account holdings of banks with the central bank, which can be regarded as a residual which balances the balance sheet. As is described in more detail in Bindseil and Seitz (2001), the normal logic of the ECB's liquidity management may be summarised as follows: The ECB attempts to provide liquidity through its monetary policy operations so that, after taking into account the effects of autonomous liquidity factors, counterparties can fulfil smoothly their reserve requirements as an average over the reserve maintenance period. If the ECB provides more or less liquidity than this benchmark, short term inter-bank interest rates will move away from the mid-point of the corridor set by the two standing facility rates. As the stylised facts above suggest, banknotes in circulation are a somewhat volatile autonomous factor, requiring from the central bank a corresponding regular adjustment of its open market operations, i.e. in the case of the ECB of its main refinancing operations. However, as evidenced in Bindseil and Seitz (2001), banknotes in circulation are by far not the most volatile item in the Eurosystem balance sheet. This role is played by government deposits, which are more than 3 times as volatile as banknotes.

To allot the appropriate amount of funds in its main refinancing operations, the Eurosystem generally prepares an autonomous factor forecast covering the pe-

riod of the tenders. In taking its allotment decisions, it normally exactly neutralises the impact of autonomous factor changes on current account holdings of counterparties, such that only the non-anticipated element of autonomous factor changes has a potentially relevant effect on liquidity conditions. These non-anticipated elements in the evolution of autonomous factors tend to follow a white noise process, reflecting the efficiency of the Eurosystem's forecasts.

It should also be noted that, from the point of view of the Eurosystem's balance sheet and its liquidity management, it makes no difference whether a reduction of the volume of outstanding banknotes is related to (a) a change of payment technology as the substitution of banknotes by cashless payments; (b) banknote de-hoarding as in the aftermath of the Y2K transmission; (c) a reduction of black money; (d) a substitution of euro banknotes abroad with dollar banknotes. From the point of view of the Eurosystem's liquidity management, it also makes no difference whether refinancing needs of banks change due to a change of banknotes in circulation, a change of government deposits, or a change of net foreign assets of the Eurosystem, since all autonomous factors are in principle treated equally.

All this suggests that the seasonality and trend of autonomous factor time series itself has *no* impact on liquidity conditions, and therefore also not on money market interest rates. Money market rates being, according to the expectations hypothesis of the term structure of interest rates, also the anchor for longer term rates, which are crucial for the macro-economy, one may conclude that the evolution of autonomous factors should per se have no influence on macro-economic variables, such as for instance the exchange rate.

In contrast to this, Sinn and Westermann (2001) argue that a change of banknotes in circulation should, via the implied change of outstanding open market operations, trigger a portfolio effect affecting the exchange rate through the bond market. First, one may note that in this case, Sinn and Westermann should not focus on banknotes in circulation, but on the total refinancing needs of banks with the central bank. Those have been influenced not only by changes in banknotes in circulation, but also by several other structural effects affecting the balance sheets of euro area central banks. For instance, total euro area reserve requirements have increased considerably through the transition to the euro in 1999 and then through the systematic growth of the reserve base. This effect certainly overcompensated the supposed decline in the banknotes in circulation in the period in which the euro was especially weak, i.e. until mid 2001. The average volume of outstanding open market operations was € 186 billion in 1999, € 215 billion in 2000, and € 218 billion in 2001 (of which € 236 billion in the first and € 205 billion in the second half). In so far, the portfolio effect described by Sinn and Westermann (2001) would have worked in the opposite direction.

Furthermore, at least in the case of the Eurosystem, the argument does not seem to be valid as the open market operations of the Eurosystem are no outright operations in bonds, but effectively *collateralised loans* which should not impact on the prices of paper used for collateralisation. This had actually been one of the motivations of why the Eurosystem, when establishing its operational framework, assigned a core role to reverse operations instead of outright opera-

tions (ECB 2001b). It is also important to note that the set of eligible papers is extremely wide and diverse (going far beyond standard Government bonds), and only a very small fraction of this paper is actually used for central bank operations by banks (out of € 6,000 billion, around € 200 billion is used). Often, these papers have no or low opportunity costs, like for instance non-Jumbo Pfandbriefe. Banks hold them purely for their interest income. In contrast to Government bonds, they cannot be used as collateral in the interbank repo market. If the bank holds paper for the income it generates, and has no use of paper such as for interbank repoing, then the use of the paper as pledge in a central bank refinancing operation is basically a free lunch. It should also be taken into account that the income generated by collateral submitted for central bank operations remains with the submitting bank, such that we indeed have, economically, a pledge arrangement.

We may conclude that after taking due account of the operational framework and the liquidity management practices of the Eurosystem, changes of banknotes in circulation should not have any direct or indirect effect on the exchange rate. This should hold independently from whether the decline of euro area banknotes involves a substitution of euro area banknotes by dollar banknotes or not as this does not make any difference from the point of view of the involved central banks' balance sheet items, money and bond markets, or interest rates.

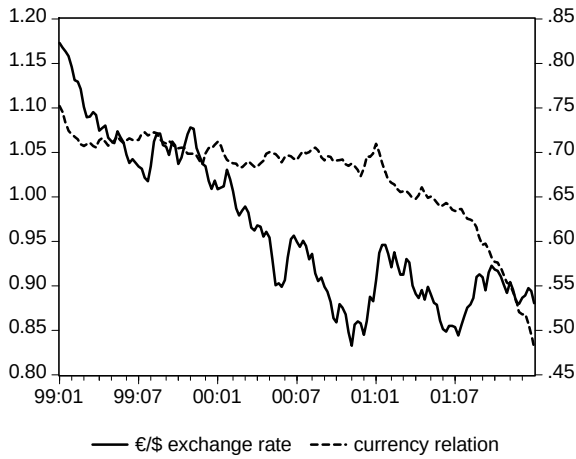
## IV. A Time Series Analysis

Are there any clear-cut hints on an empirical relationship between the evolution of euro currency in circulation and the €/$-exchange rate? To answer this question we investigate the time series under consideration, i.e. US dollar and euro currency, respectively, and the exchange rate, in more detail.

As is evident from chart 1 there is a different time pattern in the evolution of the two currencies since the end of year 2000: the downward trend in euro currency stays in sharp contrast to the continuing upward trend in US dollar currency in circulation. Chart 3 illustrates the relative movement in the two currencies together with the exchange rate since the beginning of EMU in 1999 on a weekly basis. Visual inspection suggests a positive connection for the whole sample 1999 – 2001, but a potential negative correlation for subperiods, e.g. the situation in 1999 (see for an analysis of different subperiods the following chapter). For the whole sample the correlation coefficient is 0.58. Sinn and Westermann (2001) stress the importance of the demand for euro area currencies (especially the Deutschmark) from the black economy and foreign countries for the €/$-exchange rate. A correlation between currency and the exchange rate does not need to be spurious. As already pointed out theoretically by Obstfeld and Rogoff (1996, ch. 8.3), and empirically by Seitz (1995) and Drehmann and Goodhart (2000) the US dollar exchange rate may be a good indicator for the demand for the stable currencies of the DM and the US dollar in other (unstable) countries. It should proxy the incentives for non-residents to hold dollars versus DM. The external value should indicate the relative strength and attractiveness of one currency compared to another.

*Chart 3*

**Relative Currency Movement (Right Scale) and the Exchange Rate (Left Scale)**




Notes: Relative currency movement measured by the relation of euro currency to US dollar currency

To test the thesis put forward by Sinn and Westermann (2001), we take three alternative simple approaches.

### 1. Correlation Analysis Using the Trend Component of Daily Banknotes in Circulation

In contrast to Sinn and Westermann, we argue that the adequate way to answer the question about the relationship between US dollar and euro currency in circulation as well as the €/$ exchange rate is to start from *daily* data on the relevant numbers on the *euro area* as a whole.[6] It may be misleading to look at the DM alone as the euro is made up of 12 different currencies. Let us assume for a moment that the proposition that cash exchanges from euro denominations (especially the DM) into dollars cause the euro to depreciate is correct. As the annual, monthly and weekly seasonals in the daily currency series should be due to a very large extent to domestic "official" transactions, they should have

[6] These daily data are available from the ECB's Directorate General operations upon request. As the Federal Reserve policy for daily data related to reserve factors (i.e., relating to open market operation decisions) is to give them out only up to one year prior to the current date we have to work with daily and weekly data for the US.

no connection to black economy activities and foreign demand for currency (Sumner 1990; Porter and Judson 1996). These factors should in contrast be found in the remaining trend component. And the foreign exchange rate as a financial asset price should react immediately if this trend changes because holders of euro currency switch to US dollars, possibly even triggering directly foreign exchange transactions. Therefore, we concentrate on a daily model which also allows us to isolate the intra-yearly, intra-monthly, intra-weekly and fixed and moving festivals' effects which are especially relevant for the evolution of currency (see e.g. Bindseil and Seitz 2001 for the euro area and Hamilton 1998 for the US).

In what follows we use a trend calculated from a Structural Time Series (STS) model for daily banknotes in circulation in the euro area taken from Cabrero et al. (2002).[7] Table 3 shows different correlations between this trend and the exchange rate. The window for which we calculated the correlation coefficients had a fixed length of six months and no overlapping observations. For all samples except the last half year of 2001 the correlation is negative. This negative correlation is always stronger in the first half of the years considered. The annual correlations for 1999 to 2001 are -0.77, -0.84 and -0.39, respectively. A clear-cut pattern is evident: The relation between the trend in banknotes and the €/$ exchange rate is negative. Granger causality tests support these findings. The null hypothesis that the trend component of currency does not Granger cause the exchange rate cannot be rejected at any conventional significance levels irrespective of the lags considered.[8,9]

*Table 3*

**Rolling Correlations between Currency and the Exchange Rate**

| Time period | 1/1/99-30/6/99 | 1/7/99-31/12/99 | 1/1/00-30/6/00 | 1/7/00-30/6/00 | 1/1/01-30/6/01 | 1/7/01-31/12/01 |
|---|---|---|---|---|---|---|
| Correlation coefficient | -0.87 | -0.27 | -0.77 | -0.39 | -0.91 | 0.11 |

[7] See the appendix for details on this model. Our results were unchanged if we calculated the trend via a Hodrick-Prescott-filter with the smoothing parameter $\lambda$ set to 500.000. The correlation coefficient between the two trend series is 0.99.

[8] We are aware of the problem that Granger causality tests should be interpreted with caution if one of the variables is forward looking. This should be true for the exchange rate. (We thank one of the referees for directing our attention to this point). On the other hand, parts of the exchange rate may also be backward looking. In any case, the Granger causality tests should only be considered as another descriptive statistic without any deeper structural interpretation.

[9] As unit root tests imply that the two time series are non-stationary, we also applied Granger causality tests to the differenced series. Again, the null of non-causality from currency to the exchange rate could not be rejected.

The euro area cash developments in 2001 should certainly be explained to a large extent by the euro cash changeover. But there is little evidence on the repercussions on the exchange rate. Concerning the declining currency stocks held within the euro area there are unambigous signs that these are substituted at least partially by overnight deposits of non-banks with banks. In the first seven months of 2001 currency in circulation decreased by € 28 bn. while overnight deposits increased by € 34 bn. Moreover, a money demand model for euro area M1 suggests that M1 growth in 2000/2001 is not lower than predicted by the model (ECB 2001, p. 12).

### 2. The Velocity of Circulation of Banknotes

To eliminate the effect of domestic official transactions on the trend component of currency, one may calculate the velocity of circulation of currency. As transactions variable we use seasonally adjusted private consumption in nominal terms. This measure of velocity is depicted in chart 4. As is evident, the trend of velocity has already been increasing significantly since 1997. This indicates that the volume of euro area cash in circulation might have grown more slowly in relation to private consumption on account of return flows of foreign held currency, de-hoarding of currency and the declining use of euro area cash for shadow economy transactions. Once again, one may investigate, using Granger causality tests, whether the change in the euro-dollar exchange rate is influenced by a changing trend velocity for the period 1994.1 to 2001.1. The results are qualitatively the same as with the daily data. Irrespective of differencing or not and of the lags included, the null that the exchange rate does not Granger cause velocity cannot be rejected. Estimating an equation for the velocity of circulation of currency for the same period with an opportunity cost variable (a money market interest rate) and the exchange rate as explanatory variables (in first differences) even yields a statistically significant (lagged) positive influence of the exchange rate on the velocity measure.[10]

### 3. Adding Banknotes in Circulation to an Exchange Rate Model

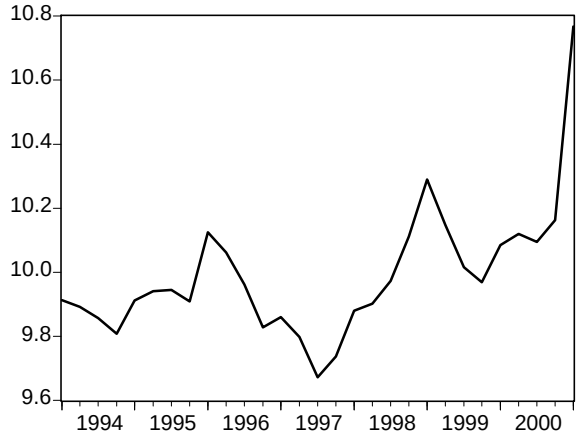
We further experimented with one of the rare exchange rate models which is able to track the performance of the euro against the US dollar until mid-2001 quite well with economic fundamentals (Sonnenholzner and Rees 2001). Furthermore, this model has the advantage to avoid the necessity of creating artificial euro area data for the time before 1999 by only using (monthly) data since the beginning of 1999. According to this model the key determinants of the €/$ exchange rate were found to be

1. The difference between Consensus growth forecasts for the US relative to Euroland: The expectation of stronger economic growth in the US is likely to result in a weaker euro.

[10] The results are available from the authors upon request.

*Chart 4*

**The Velocity of Circulation of Euro Area Cash**



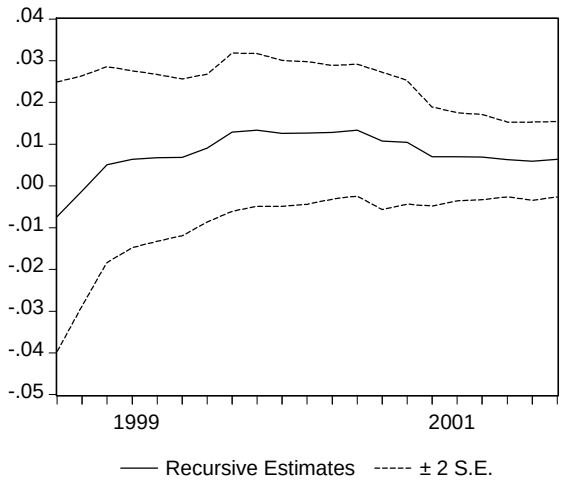

2. Bond yield differentials at the long end: In accordance with interest rate parity, higher yields in the US cause the dollar to appreciate.
3. The oil price: A rising oil price causes the euro to depreciate.
4. Relative monetary developments: In line with monetary exchange rate models higher money growth in the US relative to the euro area leads to a rise in the euro exchange rate.
5. Productivity differentials: Stronger productivity growth in the US compared to EMU boosts the dollar and depresses the euro.
6. A risk premium in the forex markets measured by the difference between the consensus exchange rate forecast and the forward rate.

Monetary developments were measured as M2 growth in the US relative to M3 growth in the euro area. We used this model and substituted relative cash developments for this proxy of 'money'. This procedure yielded a coefficient which is not significantly different from zero and reduced the fit of the equation sharply.[11] Chart 5 shows the recursive estimates of this coefficient together with the two standard error bands from mid-1999 to mid-2001. The parameter does not display too much variation but fluctuates around zero.

[11] The concrete estimation results are available from the authors upon request.

*Chart 5*

**Recursive Estimates of the Exchange Rate Coefficient**




## V. Conclusions

In this paper we analysed the evolution of cash in the euro area since the mid-nineties and especially in anticipation of the cash change-over starting at the beginning of 2002. It is confirmed that, due to the prospective introduction of euro notes and coins, the stock of euro currency in circulation has been declining since the end of 2000. However, the liquidity management practice of the Eurosystem as well as simple time series analysis of currency movements in the US and the euro area and the €/$ exchange rate, respectively, seem to argue against the claim that the depreciation of the euro is the result of exchanges of euro cash for dollar cash of foreign holders of euro area currencies and transactors in the black economy.

Finally, as a more general remark, one may question the conclusion of Sinn and Westermann (2001, p. 38) that “it could have been a mistake to introduce the euro as a virtual currency … and to allow for an extended transition period between the announcement and the physical launch of the new currency” even if the relationship between currency in circulation and the exchange rate would be such as described in their paper. The printing of the euro banknotes takes time, and only if this printing time could have been shortened, one could also have shortened the period between the announcement of the new currency and its introduction. One could of course have had the fixing of the euro conversion rates and the introduction of the currency at one date. But this would not have

solved the problem of the need to start printing the currency before its introduction. As long as one does not want to start printing the currency without this being noticed by the public, which is certainly odd, no solution to this problem seems to exist. At the contrary, it seems likely that the uncertainties that currency users would have perceived if both milestones (the fixing of conversion rates and the introduction of the currency) would have been set on one date would have been much larger, and that hence, possible fears leading to a reduction of euro area currency holdings would have been much stronger.

## Summary

This paper describes and analyses the evolution of euro area currency in circulation in the last years and especially in the run up to the cash change-over. In particular, it revisits the possible effect of the latter on the €/$-exchange rate, which has been emphasised recently in the literature. It is argued that the liquidity management of the Eurosystem fully neutralises any reduction of the banknotes in circulation by simply reducing correspondingly the funds provided to banks through its open market operations. The empirical part of the paper applies several statistical tools to investigate the three time series in question (euro banknotes, US dollar banknotes, exchange rate). The main conclusion is that there is very little evidence that the decline of the exchange rate of the euro is due to the shrinking stock of euro currency in relation to the stock of US dollar currency.

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## Appendix

### The STS Model for Daily Banknotes in Circulation

The STS model used in chapter IV is in the spirit of Harvey et al. (1997) and Koopman (1999). Their approach is to decompose a univariate time series $y_t$ (in our case banknotes in circulation) into three components which may be summarized in the following equation (1a)

(1a) $$y_t = m_t + g_t + e_t ,$$

where $m_t$ is a stochastic trend defined as a local linear trend (see below), $g_t$ is the stochastic seasonal part and $e_t$ is the irregular component modeled as an iid stochastic process with zero mean and variance $s^2$. The structure of the trend component is as follows:

(2a)
$$m_t = b_{t-1} + m_{t-1} + h_t$$
$$b_t = b_{t-1} + n_t$$

In (2a) $h_t$ and $n_t$ are iid and normally distributed processes with zero mean and standard deviation $s_h$ and $s_o$, respectively. The trend variable calculated in this way was used in the analysis in the main text in section IV. The seasonal component is defined as the sum of k subcomponents which reflect different seasonal patterns, i.e. $g_t = \sum_{i=1}^{k} g_t^i$. Every seasonal subcomponent evolves according to (3a)

(3a)
$$g_t^i = z_t^i d_t^i \,,$$

where $z_t^i$ is a fixed vector of 'time dependent' variables the values of which are defined over a limited range of the total sample T. For example, $z_t^i$ is defined over the range [1, 365] in the case of an annual seasonal pattern, and its values repeated periodically over the rest of the sample. It is guaranteed that the seasonal effects add up to zero. Finally, $d_t^i$ represents a time varying parameter which follows a random walk, i.e.

(4a)
$$d_t^i = d_{t-1}^i + x_t^i \,,$$

where $x_t^i$ is a vector of zero mean and serially uncorrelated error processes with covariance matrix equal to $s_i^2 I$. If the seasonals are deterministic, as in the case of fixed and moving festivals, $s_i^2 = 0$. Some of the stochastic seasonal components $g_t^i$ are modeled as periodic seasonal cubic splines. This is the case for the intra-yearly and intra-monthly effects. These are a succession of polynomial functions of order 3 defined over a range [0, $T_s$] to approximate the seasonal pattern ($T_s$ = 365 for an annual season, $T_s$ = 30 for a monthly season). The number and length of the subintervals within that range, known as so-called knots, varies according to the concrete seasonal pattern. The selection of the number of knots and the positioning of the splines is based upon visual inspection of the residual correlograms, goodness of fit and forecasting performance. The larger the number of knots, the better the fit, but the forecasting performance deteriorates. The final specification was one with 16 knots for the intra-yearly spline and 6 knots for the intra-monthly effects.

In the case of a deterministic season, the seasonal vector $d_{t,i}$ is modeled as follows:

(5a)
$$d_{t,i} = w_i(B)h(t_i, l) \,,$$

where $w_i(B)$ is a polynomial lag operator associated with the i-th calendar variation effect and $h(t_i l)$ is an indicator function that takes the value of 1 when $l = t_i$

and zero otherwise, where $t_i$ is a date associated with a particular calendar variation effect. Table 1a shows the structure of these different polynomials which represent fixed and moving festivals like Christmas and different national holidays (see Cabrero et al. 2002, p. 15). The polynomial backshift operators $w_i(B)$ have different coefficients for the different holidays displayed in the table. Fixed holidays correspond to January 1st, August 15th and November 1st.

*Table 1a*

**Fixed and Moving Holidays in the STS Model**

| Holiday ($\tau_i$) | $\omega_i(B)$ |
|---|---|
| Easter Friday | $(\omega_0+\omega_1B+...+\omega_{12}B^{12})B^{-4}$ |
| Ascension | $(\omega_0+\omega_1B+...+\omega_5B^5)B^{-2}$ |
| Whit Monday | $(\omega_0+\omega_1B+...+\omega_5B^5)B^{-2}$ |
| Christmas | $(\omega_0+\omega_1B+...+\omega_4B^4)B^{-2}$ |
| New Year | $(\omega_0+\omega_1B+...+\omega_5B^5)B^{-2}$ |
| Fixed Holiday | $(\omega_0+\omega_1B+...+\omega_6B^6)B^{-2}$ |

The model is then written in state space form and estimated by Maximum Likelihood using the Kalman filter.

On the basis of significance tests the total number of parameters incorporated in the model is 75. This high number is necessary to capture all the weekly, monthly and quarterly patterns. Even with this high parameterization there are still problems with the normality of the residuals and with serial correlation of the residuals (see Cabrero et al. 2002, p. 32). The latter are mainly due to the frequencies shorter than a week and to the annual frequency. Nevertheless, the correlation coefficients are small, 0.15 for serial correlation of order one and 0.13 for the annual correlation. Serial correlation could have been reduced by enriching the specification of the splines but only at the cost of decreasing the forecasting capability of the model drastically.